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THE GEOLOGY OF SOUTH MOUNTAIN AT THE JUNCTION OF BERKS, LEBANON, AND LANCASTER COUNTIES, PENNSYLVANIA

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INTRODUCTORY

The term South Mountain is applied in general to the range of high hills which enters the state of Pennsylvania from the east, extending in a southwest direction through the counties of Bucks, Northampton, Lehigh, Berks, Lancaster, and Lebanon, and thence, after a break, passing southwest through York, Cumberland, Adams, and Franklin counties into Maryland. It is a pre-Cambrian mountain range, the third or northern gneissic zone of Rogers, bounded on the north by the Paleozoic limestones and slates of the Great Valley, and on the south by the Trias. Several portions of the range, topographically prominent, bear individually the name of South Mountain and are so marked on the topographic maps issued by the United States Geological Survey.

The South Mountain of the title of this article is a ridge or elongated knob-like hill extending about nine miles east and west and four miles north and south, whose center is nearly at the junction of Berks, Lebanon, and Lancaster counties and near the intersection of parallel 40° 20′ north latitude and meridian 76° 10′ west longitude. It is nine miles west of the city of Reading and directly south of the Harrisburg division of the Philadelphia and Reading railroad. The villages of Newmanstown, Womelsdorf, Robesonia, and Wernersville lie in the Great Valley at its northern base. Fritztown is situated between the mountain and an adjacent hill on the east. Blainsport, Cocalico, and Kleinfeltersville respectively lie in the lowland to the south, southwest, and west.

The mountain crest is a divide between the drainage of the Schuylkill and the Susquehanna, streams flowing down the northwestern, northern, and eastern slopes reaching the former river via the Tulpehocken and Cacoosing creeks; while the streams rising on the southern slope empty into Cocalico Creek whose waters eventually find their way to the latter river.

TOPOGRAPHY

South Mountain rises abruptly from the valleys on all sides and is isolated from the main chain at Reading. Its persistence as a topographic form is easily accounted for by the difference in hardness between its rocks and the rocks of the neighboring valleys.

The highest altitude, 1,340 feet, is attained in the northwestern part of the mountain at a point one mile southwest of Eagle Peak, being 964 feet above the level of the valley at Wernersville. South of here and a trifle east of the intersection of the county boundaries, the summit roughly presents the appearance of a plateau with a mean altitude of 1,100 feet, dissected by the narrow gorges of Furnace Creek in the north and an unnamed stream farther east. The summit is partially cleared of trees and farming is carried on to a limited extent. Eastward the height slightly decreases and the plateau-like character gives place to a number of knobs of which Cushion Peak is the most prominent.

West of Robesonia the northwestern part is a densely wooded ridge sloping steeply toward the valley with a low escarpment facing the interior. South of Wernersville the northern slope is cleared and is the site of several sanitariums.

The southern slope is more gentle than the northern, the stream courses are not as deep, and the streams are not as long.

Directly east of Fritztown, a ridge, 500 feet high and one-half mile wide, continues for over two miles eastward, finally merging into the valley. This ridge is very significant structurally as will appear later.

HISTORY

References to the mountain in geological literature are few, although Millbaugh Hill, as it was called, was known as early as the period of the Rogers Survey. H. D. Rogers,[1] in 1858 writes, "Westward a few miles from Reading there is an insulated tract of gneiss, forming, with the sandstone of Millbaugh Hill, an elevated district, the last of the chain of the Highlands. Between the Schuylkill and Cumberland County, this is the only representative of the South Mountains of our state. The tract is about nine miles long and two wide, and extends from the Cacoosing into Millbaugh Hill." The same writer[1] mentions the distribution of the Primal strata along the northern slope. The mountain's topographic and structural features were thus early recognized by this master observer.

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[1] Henry Darwin Rogers, *The Geology of Pennsylvania*, Philadelphia, 1858, I, 93.

D'Invilliers,[2] in 1883, mentions Millbaugh Hill in a number of places in his report upon Berks County, giving minor structural details but no full description of the mountain.

The existence of gneiss and Potsdam on the mountain is briefly noted by Lesley[3] in 1885, in summarizing the geological structure of the state.

If we turn to geological maps of the region a discordance of view is manifest. The writer has not seen the atlas accompanying the Rogers Survey reports. Our information is derived wholly from the maps of the Second Survey.

A map of Lancaster County,[4] published in 1878, shows the Triassic series covering the entire northern part of the county and contiguous parts of Lebanon and Berks.

A map of the Reading region,[5] published in 1883, includes only the eastern portion of the mountain at Cushion Peak, which is shown to consist of Potsdam sandstone cut by a large trap dike on the northern slope. Potsdam sandstone likewise covers the hill east of Fritztown and extends for some distance eastward.

In 1884 appeared a map of Berks County[6] which depicted the areal geology of South Mountain in a fairly accurate manner.

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[1] *Ibid.*, 202.

[2] E. V. d'Invilliers, "The Geology of the South Mountain Belt of Berks County," *Second Geol. Survey Pennsylvania*, D 3, Vol. II, Pt. 1, 1883, vii, 50, 135–36, 204, 347.

[3] J. P. Lesley, "A Geological Hand Atlas of the Sixty-seven Counties of Pennsylvania," etc., *ibid.*, 1885, xxv, lxviii.

[4] Persifor Frazer, asst. geologist, "Grand Atlas, Geological Map of Lancaster County," *ibid.*, 1878; scale, 1 in. = 2 mi.

[5] "Geological Index Map to the Topographical Map of the Durham and Reading Hills or South Mountains," *ibid.*, 1883; scale, 1 in. = 2 mi.

[6] "Geological Map of Berks County, Compiled from the Surveys of F. Prime, E. V. d'Invilliers, R. H. Sanders, and Others," *ibid.*, 1884; scale, 1 in. = 2 mi.

According to the authors the central core consists of pre-Cambrian rocks bounded on the north, east, and west by Potsdam sandstone and on the south by the Trias. The above-mentioned trap dike at Cushion Peak is also shown.

The Hand Atlas,[1] in 1885, shows the main discrepancies above noted between the Berks and Lancaster county maps. The Lebanon County map shows Potsdam sandstone in the eastern corner.

The Lebanon County map,[2] issued in 1892, follows the Hand Atlas in regard to the distribution of the Potsdam.

According to the state map[3] of 1893, Potsdam sandstone covers the entire mountain and the hill east of Fritztown, and is cut by the trap dike at Cushion Peak.

GEOLOGY

From the preceding references it is evident that there has long been recognized on South Mountain an inlier of pre-Cambrian rocks surrounded by Cambrian sediments on the north, east, and west, and by Triassic sediments on the south.

The writer visited the region in the spring of 1911 accompanied by Mr. M. L. Jandorf of York, Pa. All available outcrops were studied. Exposures are of infrequent occurrence, however, owing to the covering of residual soil.

The boundary between pre-Cambrian and Potsdam on the west and northwest coincides with the foot of the eastward-facing scarp previously mentioned and the valley of a northern branch of Cocalico Creek. East of Eagle Peak the boundary extends in a straight line a trifle south of east for a distance of two and one-half miles bringing the pre-Cambrian down nearly to the level of the valley; thence following the base of the mountain southeastward and rising near the saddle west of Cushion Peak. From here it trends southwest for one and one-quarter miles, meeting the Trias at Laurel Ridge.

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[1] "A Geological Hand Atlas of the Sixty-seven Counties of Pennsylvania," *Second Geol. Survey Pennsylvania*, 1885, scale, 1 in. = 6 mi.

[2] R. H. Sanders, "Geological Map of Lebanon County," *ibid.*, 1892; scale, 1 in. = 2 mi.

[3] A. D. W. Smith, "Geological Map of Pennsylvania," *ibid.*, 1893; scale, 1 in. = 6 mi.

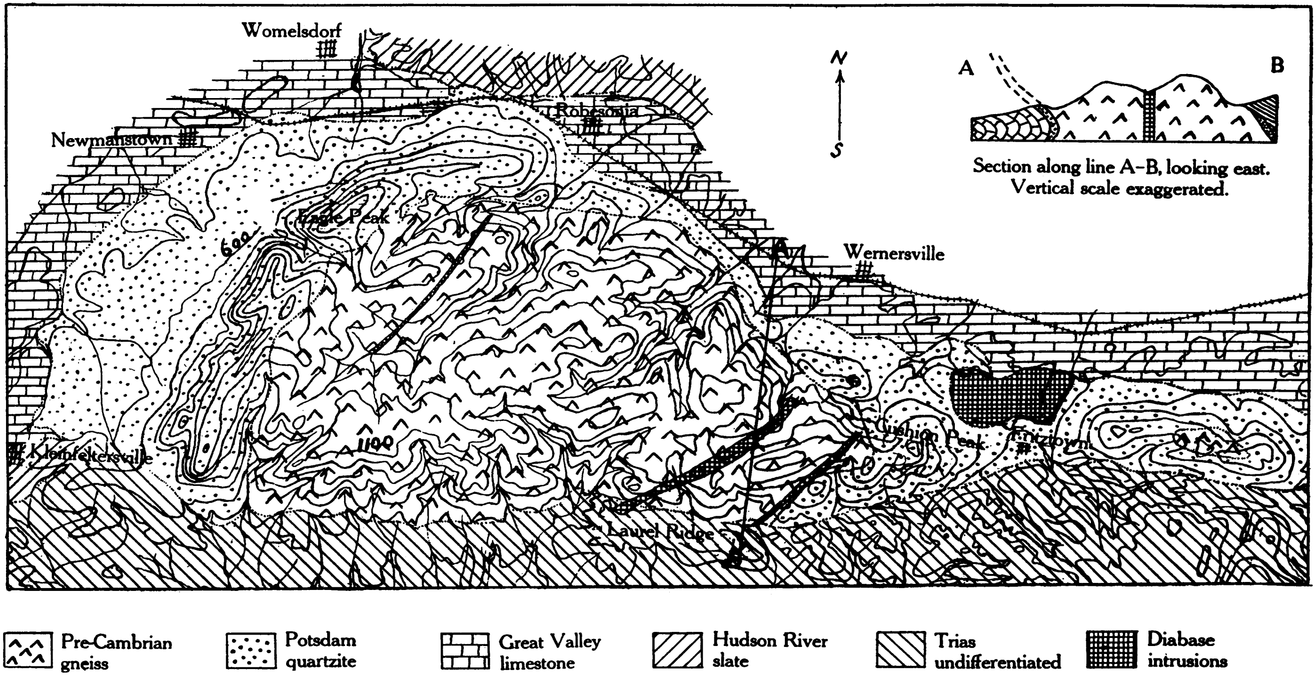

FIG. 1.—Geological map of South Mountain. Topography after U.S. Geological Survey. Contour interval, 100 feet. Scale, $\frac{1}{125,000}$

The pre-Cambrian-Triassic boundary from north of Laurel Ridge to Cocalico is approximately the southern base of the mountain. The distinct contrast in color between the lighter sandy soil of the one and the red soil of the other affords a means of accurate mapping in cases where only the decomposition products are available.

In the center of the hill east of Fritztown a small inlier of pre-Cambrian in Potsdam was found covering an oval area seven-eighths of a mile east and west by one-fourth of a mile north and south.

THE PRE-CAMBRIAN ROCKS

These comprise solid and basic gneisses cut by granite pegmatite in a complex similar to that occurring in the range at Reading and eastward. A study of thin sections shows the acid variety to be altered granite and the basic, mainly altered gabbro. From rather scanty field evidence the conclusion was reached that the granite gneiss is the younger of the two. Exposures showing the intrusion of one by the other are visible along the road and on both sides of the stream in the ravine directly southwest of the Insane Asylum. The direction of the foliation is N. 58° E.; dip 43° S.E. The close association of these two rocks is universal throughout the area, and no attempt has been made to differentiate them on the map. In general the gabbroic variety would appear to predominate in the east while granite gneiss is abundant in the western part.

Diallage is the ferro-magnesium mineral in the gabbro gneiss. A little hornblende, presumably secondary, also occurs. Magnetite is quite abundant.

Diorite gneiss covers a small area in the center of the mountain near the headwaters of Furnace Creek. Its relations to the other rocks are unknown, but it is believed to be of limited occurrence.

The granite gneiss is characterized by an abundance of alkali feldspar, more or less primary hornblende, an absence of biotite and a scarcity of muscovite.

Foliation is not marked in hand specimens of the gneisses, and in many slides can barely be detected with low magnification. The grain is uniformly medium.

These gneisses doubtless correspond very closely in composition and age with the Losee, Byram, and Pochuck gneisses of eastern Pennsylvania[1] and New Jersey.[2]

Granite pegmatite occurs in isolated outcrops along the southern slope, and in the region of the valley southwest of the Insane Asylum. The exact manner of intrusion was not noted and no attempt was made to learn the direction of veins or dikes of this rock. Megascopically, the pegmatite is a coarse-grained binary granite composed of pink microcline and bluish quartz. That muscovite occurs sporadically in large bunches or pockets is evidenced by the abandoned workings of a mica mine situated on southwestern part of the plateau near the Lebanon-Lancaster county line.

PALEOZOIC ROCKS

Cambrian System; Potsdam Formation

The basal member of the Cambrian system is the Primal White Sandstone of Rogers, or the Potsdam Sandstone of the Second Geological Survey. On paleontologic evidence Walcott[3] correlates the Reading quartzite with the Chickies quartzite of Lancaster County, and with the quartzite of the South Mountain in York, Cumberland, and Adams counties. The same rock in Lehigh and Northampton counties is correlated by Peck[4] with the Hellam quartzite of York County, and the Hardyston quartzite of northern New Jersey.

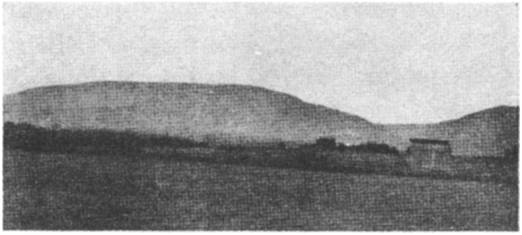

FIG. 2.—South Mountain from a distance of $1\frac{1}{2}$ miles, looking southeast from Newmanstown. The northern flanking ridge of quartzite is here shown. East of the notch it is known as Eagle Peak.

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[1] Personal communication, by Dr. E. T. Wherry and Mr. E. L. Estabrook.

[2] H. B. Kümmel, "Geological Section of New Jersey," *Jour. Geol.*, XVII, No. 4, 1909, 352–53.

[3] C. D. Walcott, "The Cambrian Rocks of Pennsylvania." *U.S. Geol. Surv.*, No. 134, 1896, 29–33.

[4] F. B. Peck, "Basal Conglomerate in Lehigh and Northampton Counties, Pennsylvania," *Geol. Soc. Amer., Bull.*, XIV (1903), 521.

It is a hard, compact quartzite, usually white in color, weathering to white sand, and varying in texture from a rather fine basal quartz conglomerate to a whitish or reddish rock resembling jasper. Data for calculating the thickness of this formation on South Mountain are wanting. D'Invilliers[1] estimates the thickness around Reading at about 300 feet. Dr. Peck[2] assumes a thickness of 300 or more feet in Lehigh and Northampton counties.

The quartzite lies unconformably upon the gneisses and doubtless formerly covered the mountain, although south of the Eagle Peak ridge no vestiges of it now remain. The scattered outliers of this formation on the gneiss of the Reading hills attest its once universal extent throughout the region.

The greatest width of quartzite is roughly two and one-half miles measured eastward from the bed of Mill Creek north of Kleinfeltersville.

East of Newmanstown the northern boundary nearly coincides with the railroad track for a distance of three and three-quarter miles, the width of outcrop of the quartzite decreasing rapidly until at Robesonia barely one-half mile of the rock intervenes between limestone and gneiss. From Robesonia eastward the quartzite steadily narrows until directly west of the Insane Asylum its width for the distance of a mile cannot exceed one-quarter of a mile and at one point is scarcely 200 yards. Thence eastward the northern boundary maintains an easterly direction, passing one-half mile north of Cushion Peak and along the northern foot of the hill east of Fritztown. The width of outcrop west of Cushion Peak is one and one-half miles. A tongue of quartzite, one-half mile wide, extends southwest from Cushion Peak to Laurel Ridge where it is concealed by the Triassic cover. Potsdam is not seen along the southern border west of this locality. The width of outcrop east of Fritztown is about one mile, the southern boundary maintaining a general easterly direction.

Great Valley Limestone

The Potsdam quartzite is conformably overlain by limestone of the Great Valley series everywhere along the northern border, with one doubtful exception discussed below. As the limestone enters only indirectly into the present problem no further description of it will be given. Its Cambrian age has been shown by Walcott[1] and others.[2]

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[1] *Op. cit.*, 102.

[2] *Op. cit.*, 520.

Ordovician System; Hudson River Formation

NOTE.—This formation in southern Pennsylvania is correlated with the Martinsburg shale of West Virginia by the U.S. Geological Survey.[3]

On the extreme western edge of the map at the village of Kleinfeltersville and near the Triassic border appears a small area of slates, being probably the eastern end of an inlier of the Hudson River formation mentioned by Lesley[4] and shown on the maps of the Second Geological Survey.

One-half mile west of Robesonia near the railroad a bluish slate lies either directly upon the Potsdam quartzite or in close juxtaposition. This is the southern limit of a belt of Hudson River slates according to the maps of the Second Geological Survey. Dr. Wherry[5] has frequently found beds of slate intercalated in the Cambrian limestones and thinks that the Second Geological Survey was in error in mapping as Hudson River certain slate areas in the South Mountain region. The question as to the age of the slate at this locality may be regarded as not yet definitely settled. The possible existence here of a strike fault of some magnitude, cutting out the limestones and bringing Hudson River and Potsdam in contact, is admitted, but data relative to any such dislocation are wanting. From the fact that the slate is underlain by limestone in many places along the belt it would seem that the maps of the Second Geological Survey give the correct interpretation. The apparent unconformable overlap of the Hudson River slate upon the Cambrian formations is a point worthy of further study.

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[1] *Op. cit.*, 29–33.

[2] F. B. Peck, "The Cement Belt in Lehigh and Northampton Counties of Pennsylvania. A Description of the Geological Formations," *Mines and Minerals*, XXV, No. 2, 1904, 54; *idem, Econ. Geol.*, III, No. 1, 1908, 41.

G. W. Stose, "The Cambro-Ordovician Limestones of the Appalachian Valley in Southern Pennsylvania," *Jour. Geol.*, XVI, No. 8, 1908, 698–703.

H. Justin Roddy, "The Lower Cambrian of Lancaster County, Pennsylvania" (abstract), *Science*, N.S., XXX, No. 769, 1909, 415.

E. T. Wherry, "The Early Paleozoic of the Lehigh Valley District, Pennsylvania" (abstract), *Science*, N.S., XXX, No. 769, 1909, 416.

[3] G. W. Stose, "Mercersburg-Chambersburg (Pa.) Folio," *U.S. Geol. Surv.*, No. 170, 1909, 10.

[4] *Op. cit.*, lxviii.

[5] Personal communication.

MESOZOIC ROCKS

Triassic System; Newark Series

The Newark is undifferentiated on the map. East of Cushion Peak basic igneous rocks of the diabase type form the southern boundary; westward the Newark rocks adjacent to the mountain consist of red basal conglomerate with quartzite pebbles and sandstone dipping gently south. The southern base of South Mountain was locally part of the northern border of the Triassic Sea.

Structure

Rogers[1] attributes the width of outcrop of the quartzite south of Newmanstown to "the presence of two or three anticlinal flexures." It was impossible either to verify or disprove this view during the present investigation. In the dense woods of oak and chestnut west of Eagle Peak outcrops are few and the above statement would seem to imply a hasty generalization from very meager data. One outcrop on the western slope of the mountain gave a strike N. 60° E., and a dip 70° N.W. Mr. J. H. Eby,[2] a mining engineer formerly of Mountville, Pa., states that the quartzite at Eagle Peak and farther west dips into the mountain. Whatever the truth may be concerning any minor undulations, the northwestern slope of South Mountain probably represents a steep upbuckling of the quartzite decreasing in dip toward the valley, with a possible slight overturn near the gneiss.

From Robesonia eastward the structure becomes more apparent, coincident with the narrowing of the quartzite outcrop. A short distance south of the Robesonia iron furnace the quartzite was observed to dip south into the mountain at an angle of 47° within a few hundred feet of the gneiss. Wherever limestone was observed near the quartzite from Robesonia to Wernersville and farther eastward, the dips were universally south toward the mountain. On the Insane Asylum grounds a large outcrop of limestone occurs near the quartzite where the latter is narrowest. The beds here are vertical.

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[1] *Op. cit.*, 202.

[2] Personal letter.

One and one-quarter miles south of Wernersville quartzite overlies limestone in a quarry, both dipping 60° S. The patch of limestone at this point probably is an outlier on the quartzite of a few acres' extent along a synclinal axis, although the exact position of the quartzite-limestone boundary in this vicinity is in doubt, and the outcrop may possibly be on the boundary.

From the above facts it would seem probable that along the northern side of the mountain, particularly east of Robesonia, the Paleozoic sediments of the valley are overturned toward the north near their contact with the crystallines. This does not imply a great overlapping of the gneiss on the Paleozoics, and no fair interpreter could so construe the facts; but that, during the period of Appalachian folding when all the rocks were subjected to tangential pressure, the force acting from the south found expression in the northern part of South Mountain by an upward arching and slight overturn of the quartzite and limestone.

The possible existence of strike faults along the northern slope has been carefully considered but no evidence on this point was found. The writer is aware that certain geologists have demonstrated the efficacy of faults in bringing portions of the pre-Cambrian range above the Paleozoics of the Great Valley, but at the locality in question it would seem safer to give preference to the folding hypothesis until the region has been mapped in greater detail.

On the crest of the hill east of Fritztown the evidence in favor of overturning seems conclusive. The quartzite on both sides of the small pre-Cambrian inlier dips to the south. The structure of this hill thus epitomizes the structure of South Mountain.

In connection with the above interpretation it is instructive to note the observations in counties to the east of one long familiar with the same formations and general structural conditions. Dr.

Peck[1] found the quartzite overturned at one place, its beds dipping south toward gneiss.

He[2] has shown that the limestones in the Cement Belt have been overturned to the north and northwest in several localities to such a degree as to make probable a crustal shortening of 6 to 1.

The complicated structure of the South Mountain in York, Cumberland, Adams, and Franklin counties is generally conceded[3] to be due to overthrust faulting acting from east to west, bringing pre-Cambrian volcanics in contact with lower Cambrian quartzite. Within recent years, however, one observer[4] has described it as an anticlinorium with Lower Cambrian strata "in unbroken sequence" showing vertical or overturned dips on the northwest side. If the latter interpretation be correct, this mountain would seem to be similar, in major structural lineaments, to its smaller neighbor to the northeast described in the preceding pages.

DIKES

Three diabase dikes were traced for average distances of two miles, and others doubtless escaped observation. The general trend is northeast by southwest. The width of each can be inferred only approximately from surface float, being presumably but a few feet in the case of both the easternmost and westernmost dikes. The dike north of Laurel Ridge is the largest with a width of at least 200 feet. This dike cuts the Triassic conglomerate at Laurel Ridge, and thus its period of intrusion may easily be inferred. The dike rock is an olivine free diabase of fine texture. These dikes in the eastern part of the mountain possibly extend farther south and may be the northern portions of dikes depicted on the Lancaster county maps.

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[1] F. B. Peck, "Basal Conglomerate in Lehigh and Northampton Counties, Pennsylvania," *Geol. Soc. Amer., Bull.*, XIV (1903), 520.

[2] F. B. Peck, "Geology of the Cement Belt in Lehigh and Northampton Counties, Pennsylvania," etc., *Econ. Geol.*, III, No. 1, 1908, 52–55; *idem, op. cit., Mines and Minerals*, XXV, No. 2, 1904, 56.

[3] C. D. Walcott, "Notes on the Cambrian Rocks of Pennsylvania and Maryland from the Susquehanna to the Potomac," *Am. Jour. Sci.*, 3d Ser., XLIV (1892), 477, 479–80; F. Bascom, "Volcanic Rocks of South Mountain, Pennsylvania," *U.S. Geol. Surv. Bull.* No. 136, 1896, 30; E. T. Wherry, "The Copper Deposits of Franklin-Adams Counties, Pennsylvania," *Franklin Inst. Jour.*, February, 1911, 153 (hypothetical structure sections).

[4] G. W. Stose, "The Sedimentary Rocks of South Mountain, Pennsylvania," *Jour. Geol.*, XIV, No. 3, 1906, 212, 216, 219–20; *idem*, "White Clays of South Mountain, Pennsylvania," *U.S. Geol. Surv. Bull.*, No. 315, 1907, 322–23.

There is an oval mass of diabase northeast of Cushion Peak and north of Fritztown covering an area one and one-quarter miles east and west by one-half mile north and south. D'Invilliers[1] mentions a trap dike cutting the sandstone and limestone at this point, and infers a long northern extension of the same. Several of the above-mentioned maps likewise graphically express this view. This inference would seem to be erroneous, careful search failing to reveal the northeastern continuation of the igneous rock. This diabase mass is probably a boss of the same age as the dikes of the mountain.

SUMMARY

This study has aimed to emphasize the following points:

South Mountain structurally and topographically is a unit, its central core being an inlier of slightly metamorphosed acid and basic pre-Cambrian eruptives, flanked on the north by Cambrian sediments, and its southern base the local northern limit of the Triassic transgressional sea. During the Appalachian revolution the Cambrian quartzite, which may once have covered the summit, was up-arched and probably slightly overturned in the northwestern part of the mountain, while in the northeastern part it was overturned upon the limestone of the Great Valley. The Triassic sediments along the southern base of the mountain show a slight tilting to the south. The diabase intrusions cut the Trias, and presumably belong to the same period of eruptive activity whose evidences are so common elsewhere throughout the East. The physiographic prominence of the mountain is due to the superior hardness of its rocks.

The writer's sincere thanks are due to Mr. Eby for the contribution of valuable data. Dr. M. E. Wadsworth, of the School of Mines, University of Pittsburgh, and Dr. C. R. Eastman, of the University of Pittsburgh and Carnegie Institute, have aided in suggestions; Mr. Jandorf has ably assisted in the field; and Dr. Wherry and Mr. Estabrook, of Lehigh University, have helped in correlation.

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[1] *Op. cit.*, vii, 204.